International Journal of Scientific Research in Chemistry (IJSRCH) | ISSN: 2456-8457
© 2018 IJSRCH | Volume 3 | Issue 5

Scanning Electron Microscopic Analysis of a Sucrose Composite Propellant

Iguniwei B. Paul*, Okunola M. Rhoda, Fatima Abubakar
Department of Applied Chemistry, College of Science and Technology, Kaduna Polytechnic, Kaduna, Nigeria

ABSTRACT

Composite materials are unique because they possess advantages that the individual combining materials do not have. A sucrose composite propellant was prepared using two different methods. And they were then subjected to Scanning Electron Microscopic analysis, which revealed the topography and morphology of a composite that has a particulate KN03 crystals dispersed in a random manner undissolved in a sucrose continuous matrix phase. The sucrose also acted as the binder of the whole composite. Giving the composite a unique propelling ability not available in the sucrose alone or the potassium nitrate alone.
Keywords: Composite, Sucrose, Sugar, SEM, KNO3, Propellant, Topography and Morphology.

I. INTRODUCTION

A composite material is made by combining two or more materials – often ones that have very different properties. It can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone [1]. The two materials work together to give the composite unique properties. However, within the composite the different materials can be identified individually as they do not dissolve or blend into each other. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. The two constituents are a reinforcement and a matrix (asminternational.org). Most composites are made of just two materials. One is the matrix or binder. It surrounds and binds together fibres or fragments of the other material, which is called the reinforcement [2]. In this context sucrose, a disaccharide Sugar is the Matrix and also the binder which is reinforced with Potassium nitrate as the particulate material. These two material also function as both a fuel and a binder and an oxidizer [3]. The potassium nitrate Sugar composite, abbreviated as KNSU finds major use as a propellant in solid rocketry propulsion [4]. Four common methods are used to prepare sugar composite propellants: (i) Dry Ramming (ii) Melting / Casting (iii) Moist pressing (iv) Re-crystallization. Melting/casting is the most common method used. This is because it's the most efficient method for quick preparation and uniform homogenicity of the KNSU mix. Sugar composite propellants like the KNSU are moderate performance propellants in which the binder fuel is one of the common sugars (sucrose, dextrose & maltose etc). Potassium nitrate will not burn at all on its own, unless it is presented with a fuel source like sugar.

The use of the scanning electron microscopy (SEM) will enable the microscopic understanding of the composite morphology and topography visavis how the individual material forms the composite. [5].This will further clarify the propellant performance as deduced by the proponents of the melt and cast method as being the best form of preparation over the other methods. Interestingly, extensive literature search for related work yielded some results but in a slightly different sugar composite. Sugar cane pulp was combined with phenolic formaldehyde to produce a sugar phenolic resin composite [6]. Unlike this research, where the sucrose crystals is the matrix material, the sugar cane stalk/pulp is the particulate/reinforcement material. The sugar pulp was made to undergo processing in to granules through a method developed by [7]. This method for preparing the sugar pulp contrast the method used for the sugar composite of this work. A modified melt and cast method by Nakka (1984) and Dry ramming method by Smiley (2013) were used. It is noteworthy that Leite et al (2004) used the sugar cane pulp in producing their sugar composite, while the Sugar crystals extracted from the liquid syrup was used in producing the sugar composite in this research work. The overall aim of Leite and co-workers was to produce a composite with superior mechanical properties like resistance to impact etc. This objective is contrasted by the purpose of this research which is to analyse which method of composite preparation produces a better propellant based on the microscopic interaction of the materials involved. SEM analysis of Leite and co-workers work showed in summary how the ratio of the pulp to the phenolic resin can impact on the overall strength of the composite. This also contrasted the outcome of this research which showed the flaws normally not seen with the naked eye but can be deduced from the performance of the composite propellant [8] due to the poor mixture/bonding of the KNO3 to the sucrose matrix as exposed by the SEM result.

II. MATERIAL AND METHODS

(i) Sucrose (ii) Potassium Nitrate (iii) anti moisture polythene bag (iv) Glass tubes (v) PVC sheet (vi) Acrylic Adhesive (vii) Heating Pan (viii) Heat resistant Thermometer (ix) Glass stirrer and ramming tool (x) Measuring tape and Ruler (xi) Hand gloves (xii) Goggles (xiii) Digital Weighing Balance (xiv) Thermostat controlled heat Source (xv) Dust mask (xvi) Desiccator (xvii) Ceramic mortar and pestle.

(A) Sample Collection:

Five hundred grams (500) of sugar (sucrose) manufactured by BUA group of Companies was obtained from the market, and was used without further purification. Industrial grade potassium nitrate was obtained from a chemical store. The sugar was kept sealed in the laboratory while the potassium nitrate was kept in its container as it was bought in

(B) Preparation:

A modified Melt and Cast method of [7] and the Dry ramming method by [8] was used in the production of the composite propellant for this research work. This method involves grinding the sugar and potassium nitrate separately in to powdery form (to increase their surface area) and melting the sugar and mixed with potassium nitrate, making a batch of 200grams of the KNSU mix, in a ratio of 65% KNO3 and Sucrose 35%. This mixture was done slowly! (To avoid a deflagration) The mixture was further heated using a hot plate to a melting temperature of 1800C forming a viscous paste, which was quickly poured into the glass tubes (Plate 1) It was allowed to cool, and was stored in a desiccator to prevent contact with moisture. Another batch of the same mix ratio was dry rammed into another glass tube. The following precautions were taken: (i) Grinding to powder form was done very slowly to avoid sugar dust explosion. (ii) Face protection in the form of wearing a goggle and dust mask was ensued. (iii) Continuous stirring was ensured while keeping the temperature below 200oC so as to avoid charring and carbonization. Lab coat and hand gloves were worn. (iv). It was ensured that the desiccator stays closed at all times before the composite samples were taken for SEM analysis.

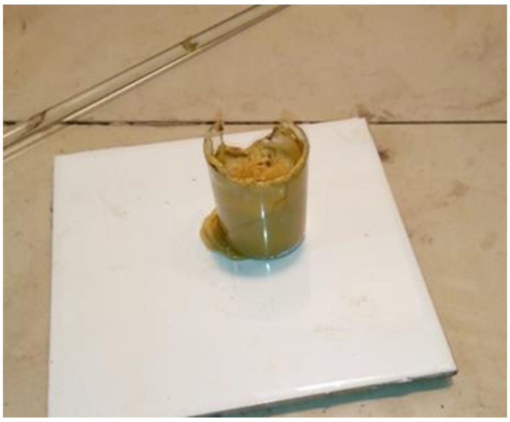

Plate 1: Casted Composite in Glass Tube

III. RESULTS AND DISCUSSION

(A) Results

The Sugar composite was successfully produced using the two different methods of Dry ramming and Melt and cast (plate 2) It was preserved in a desiccator so as to prevent moisture from being absorbed by the composite.

Plate 2: Prepared Sucrose Composites

Key: White sample = dry rammed composite.
Brown sample = melt and casted composite.

Below are the SEM micrographs of the dry rammed composite and the melt and cast composite

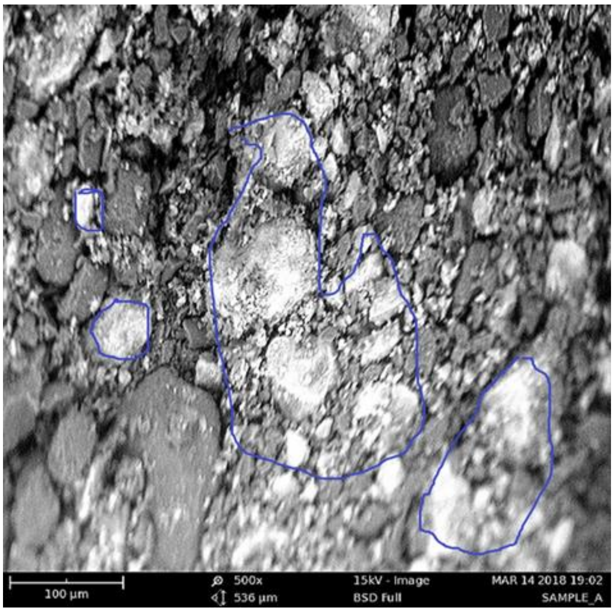

Plate 4.2 Dry rammed Composite Micrograph

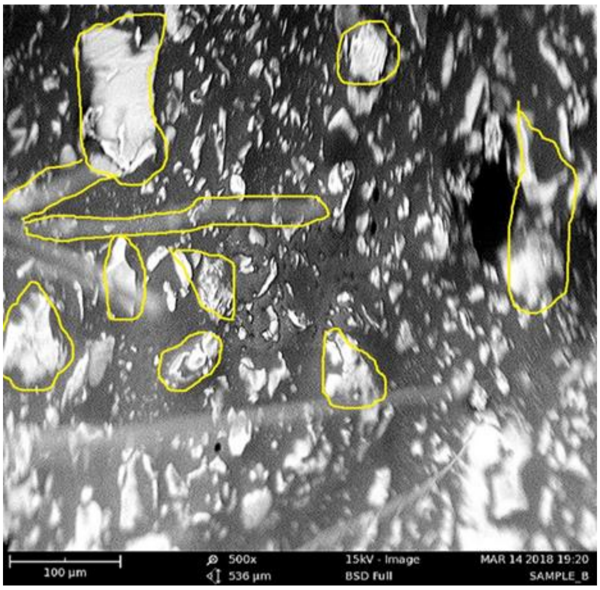

Plate 3: Melt and Cast Composite Micrograph

(B) Discussion:

A Sugar composite propellant was produced using two different methods, namely (i) Dry ramming and (ii) Melt and Cast successfully (Plate 1) The composite produced by dry ramming maintained the white colour of the separate sucrose and potassium nitrate, while that of the melt and cast composite lost its characteristic white colour, likely due to the heat absorbed by the materials during melting. The samples were then subjected to Scanning electron microscopic analysis.

The micrograph of the dry rammed sample (plate 2) were magnified 500 times. The blue areas circled indicates the presence of potassium nitrate crystals that obviously did not suffer mechanical crystal deformation though it was rammed together with the sucrose, and confirms that it acts as the particulate reinforcing the sucrose that act as the matrix as seen by the dark continuous phase topography on the micrograph.

The micrograph of the melt and cast sample (plate 3) indicates a continuous dark matrix phase with irregular disruptive white particles in various shapes and sizes. This disruptive particulates can be inferred to be potassium nitrate crystals since its melting point is at 334^{0}C while that of sucrose is 180^{0}C. Because sucrose melt first and faster, we can see the flow characteristic in the form of the continuous phase topography of the dark heated sucrose. Some of the KNO_3 crystals took a submarine position as seen at the top right side of plate 3 micrograph. Despite this lack of complete fusion between the two materials, the composite still exhibited the true behavior of a composite. Chiefly because sucrose also acts as a binder decomposing very fast because of the oxygen contained in it.

IV. CONCLUSION

A sucrose composite propellant was prepared successfully using two different methods. Scanning Electron Microscopic analysis was done on the composites. It revealed that dry rammed composite had less cohesion topographically, as the KNO_3 crystals are not in a continuous fused state with the sucrose bulk phase. That of the Melt and cast shows some significant cohesion and fusion topographically and morphologically, as there is much more sucrose matrix permeating the whole space with fewer particulate disruptions and reduced particulate sizes. With some of the KNO_3 crystals taking a submarine nature in the continuous sucrose phase. This further confirms that the KNO_3 crystals did not melt and dissolved in to the sucrose matrix, but was held by the binding character of the sugar.

V. ACKNOWLEDGMENT

I am grateful to Shuaibu Abbo, a graduating student of Applied Science Department, Kaduna Polytechnic, for his dedication in the Laboratory. The knowledge of Chemistry research should never leave you.

IV. REFERENCES

[1]. T. Composite Materials (n.d.). Retrieved from http://www.rsc.org/Education/Teachers/Resources/Inspirational/resources/4.3.1.pdf
[2]. Bisanda, E.T.N.(1993) The Manufacture of Roofing Panels From Sisal Fibre Reinforced Composites. *J. Mater. Proc. Technol*, vol. 38, pp. 369-380.
[3]. Lesilie, S. & Yawn, J. (2002) Proposal for the inclusion of KNO3/Sugar Propellants in the Tripoli Research Agency (TRA) Experimental Rocketry Program. A Technical Report Retrieved from www.4sightinc.com/stu/docs/sugar_Pro_Proposal.pdf
[4]. Nakka, R.A. (2007) Sugar Motors. Retrieved from www.nakka-rocketry.net
[5]. Introduction to Composite materials (na) Retrieved from https://www.asminternational.org/documents/10192/1849770/05287G_Sample_Chapter.pdf
[6]. Leite, J. L., Pires, A. T. N., Ulson de Souza S. M. A. G. and Ulson de Souza A. A. (2004) Characterization of a Phenolic Resin and Sugar

cane Pulp Composite. *Brazilian Journal of Chemical Engineering.* 21(2), 253 - 260.

[7]. Neto et al (1996) Isolation and Characterization of a Lignin-Like Polymer of the Cork of Quercus suber L. Holzforschung-International *Journal of the Biology, Chemistry, Physics and Technology of Wood,* 50(6), 563-568.

[8]. Smiley, J. (2013) Easy PVC Rockets.pdf. Create space Independent Publishing. Retrieved from www.amazon.com

[9]. Nakka, R.A. (1984) Solid Propellant Rocket Motor Design and Testing. A Thesis Presented to the Department of Mechanical Engineering, University of Manitoba

[10]. Smiley, J. (2013) Easy PVC Rockets.pdf. Create space Independent Publishing. Retrieved from www.amazon.com